NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO
ATTN OF:

March 27, 1971

TO: USI/Scientific & Technical Information Division
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures contained in the Code GP to Code USI memorandum on this subject, dated June 8, 1970, the attached NASA-owned U.S. patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No. : 3,360,798

Corporate Source : Radio Corporation of America
Princeton, New Jersey

Supplementary
Corporate Source :

NASA Patent Case No.: XMS-03454

Please note that this patent covers an invention made by an employee of a NASA contractor. Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of Column No. 1 of the Specification, following the words ". . . with respect to an invention of. . . ."

G Parker

Gayle Parker

Enclosure:
Copy of Patent

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Dec. 26, 1967 JAMES E. WEBB 3,360,798

ADMINISTRATOR OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

COLLAPSIBLE REFLECTOR

Filed Jan. 13, 1965 3 Sheets-Sheet 1

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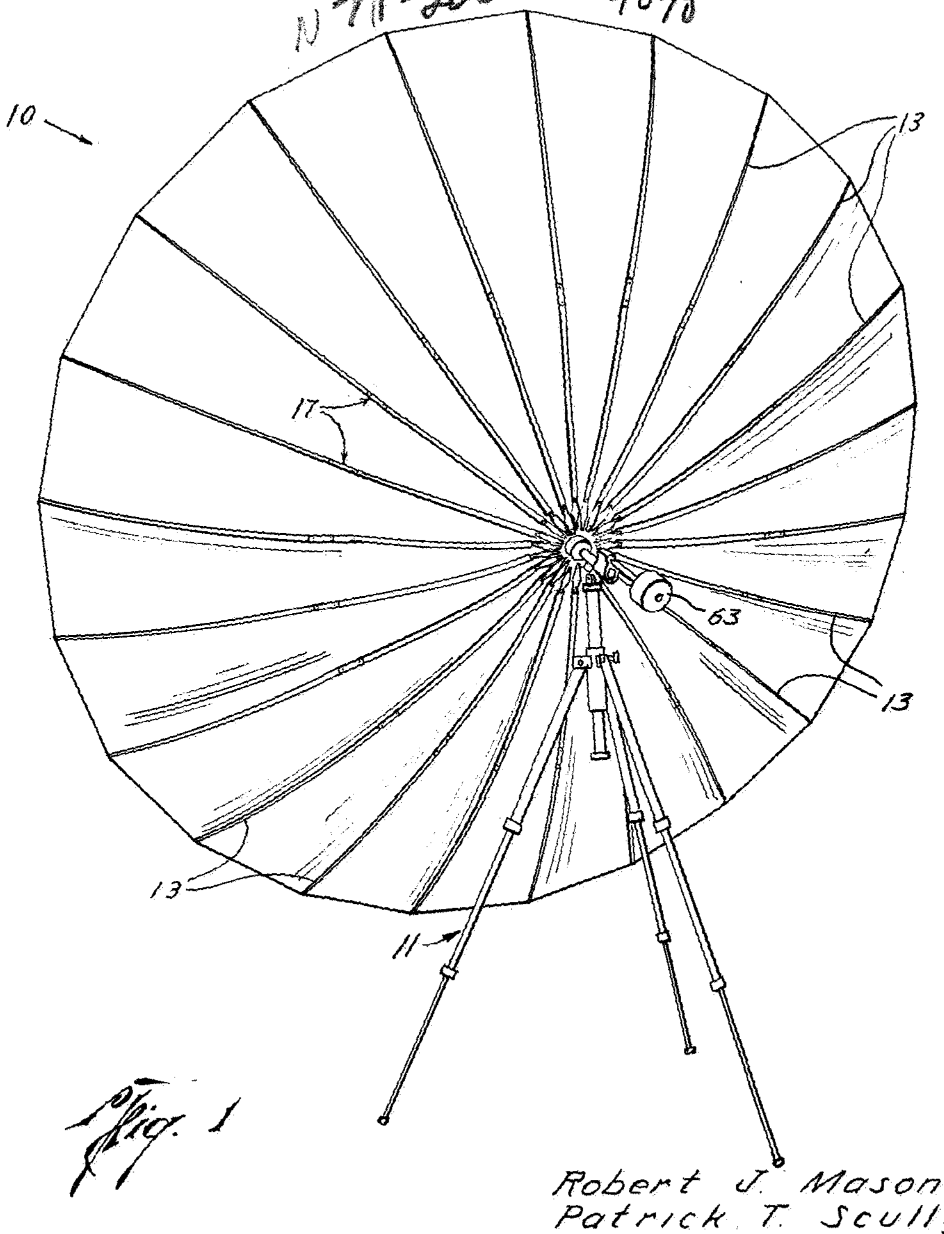


Fig. 1

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Fig. 2

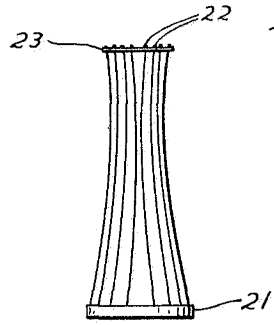



Fig. 3

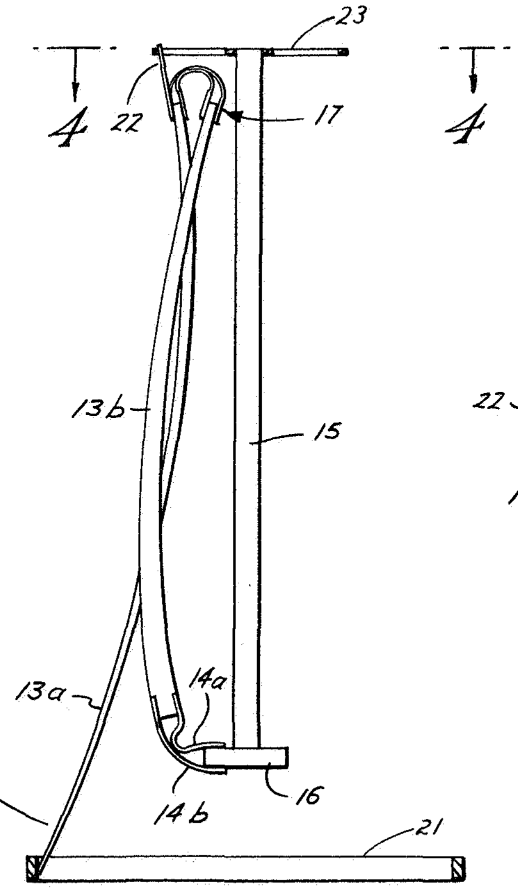
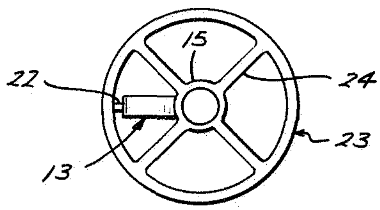



Fig. 4

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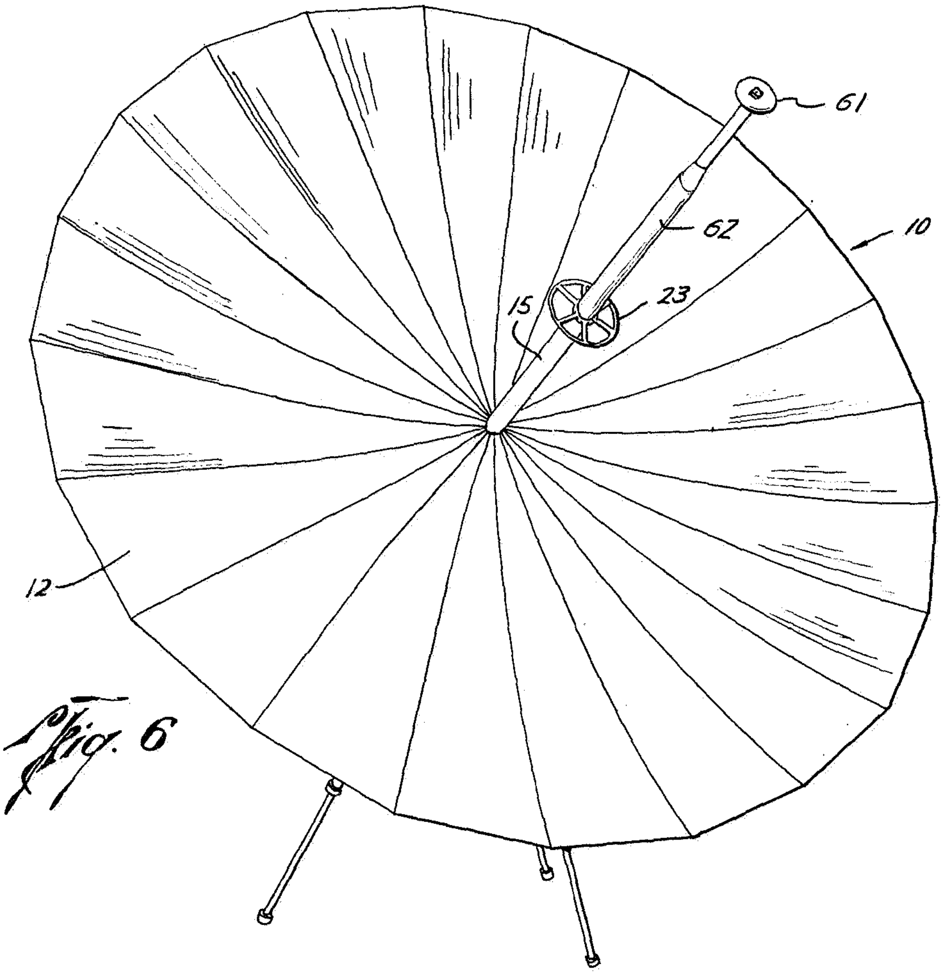


Fig. 6

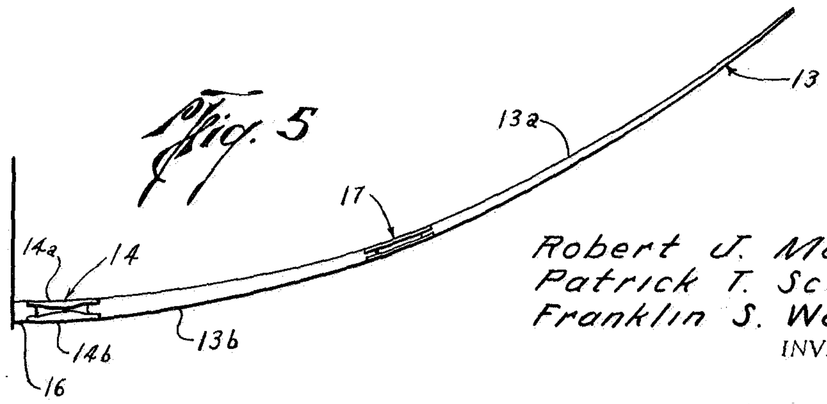


Fig. 5

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**United States Patent Office** 3,360,798 Patented Dec. 26, 1967



# 3,360,798
# COLLAPSIBLE REFLECTOR

**James E. Webb, administrator of the National Aeronautics and Space Administration with respect to an invention of Robert J. Mason, Levittown, Pa., Patrick T. Scully, Moorestown, and Franklin S. Wezner, Camden, N.J.**

**Filed Jan. 13, 1965, Ser. No. 425,363**
**10 Claims. (Cl. 343—915)**

## ABSTRACT OF THE DISCLOSURE

An automatically erecting reflector in the form of a paraboloid of revolution which utilizes leaf springs for erecting the reflector from an original packaged condition. A flexible reflective sheet is stretched across articulated ribs, each of which is foldable at a leaf spring joint near its mid-point and at an end junction where it is joined by leaf spring members at the vertex of the paraboloid to an axial elongate member. The resilient leaf springs bias the ribs to a normally unfolded condition. In its packaged condition, the ribs are folded and held against the axial member by latching tabs, one on each rib near its mid-point, and which are releasably engaged with a holding ring affixed to the axial member. The free ends of the ribs are held adjacent the axial member by an encompassing retainer band. By removing the retainer band, the leaf spring connections urge the ribs to unfolded condition whereby the latching tab of each rib is unlatched from the axial member and the reflector assumes its operational configuration of a paraboloid of revolution.

The invention described herein was made in the performance of work under a NASA contract and is subject to the provision of Section 305 of the National Aeronautics and Space Act of 1958. Public Law 85–568 (72 Stat. 435); U.S.C. 2457.

This invention relates to folding reflectors, and more particularly to a collapsible, foldable reflector for reflecting radiant energy.

Reflectors for microwave energy, as used in antenna systems, are frequently in the shape of a paraboloid of revolution. For normal operating frequencies such as S-band frequencies, the size of the reflector is frequently so large as to present problems with respect to mobility and portability. For example, it is usually impractical or impossible to store such a reflector in its operational configuration in a spacecraft where space is at a premium. It is therefore desirable that such a reflector be collapsible to small size and be simple to erect so that it can be stored in flight and may be erected rapidly and simply when its use is required. It is also desirable that reflectors to be used in space exploration have a minimum of relatively moving parts to reduce the possibility of cold welding of parts in the hard vacuum environment, and to minimize the use of exotic materials and lubricants for bearing surfaces.

Although many types of folding reflectors are known in the prior art, all have disadvantages which limit their suitability for use in vacuum environments and affect their desirability in other applications. Most prior art reflectors utilize hinged connections and sliding parts which are not to be desired in space applications. In addition, they generally employ auxiliary means for locking the reflector in its erected configuration which only adds to the total weight and complexity of the reflector.

The reflector of this invention which is designed to overcome the attendant disadvantages in the prior art devices is an automatically erecting paraboloid of revolution which utilizes the elastic energy of leaf springs for unfurling and erecting the paraboloid. The reflecting surface is provided by a thin membrane stretched across articulated ribs which have the form of sectors of the paraboloid. Each rib is articulated at approximately its midpoint and at an end junction where it is joined at the vertex of the paraboloid to an elongate member which defines the axis of the paraboloid. Thin metallic leaf springs make up the connection at each articulation joint and provide the energy required for erection.



In its packaged condition the ribs of the reflector are folded at their midpoint articulation joints and the free ends of the ribs are held adjacent the axial member by an annular retainer band. The folded ribs are also held against the axial member at their midpoint folds by latching tabs which are attached to each rib near its midpoint articulation joint and are releasably engaged with the axial member. Upon removal of the retainer band the leaf spring connections urge the ribs to unfurled condition whereby the latching tab of each rib is unlatched from the axial member, and as the springs snap into rigid condition the reflector assumes its operational configuration of a paraboloid of revolution. In the erected configuration the rigid springs lock the ribs in their curved shaped and provide the parabolic contour of the reflector.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same become better understood by reference to the following detailed description when considered in connection with the accompanying drawings in which like reference numerals designate like parts throughout the figures thereof and wherein:

FIGURE 1 is a perspective view of the back side of the reflector of this invention in its erected configuration when mounted on a tripod stand and used as a reflector for microwave energy;

FIGURE 2 is a view showing the reflector in its packaged configuration;

FIGURE 3 is a schematic view of the axial member of the reflector and showing one of the parabolic ribs held thereagainst in folded condition;

FIGURE 4 is a plan view of a dielectric retaining ring on the axial member to which the folded ribs are releasably attached when in folded condition;

FIGURE 5 is a side view of one of the articulated ribs of the reflector when in erected configuration; and

FIGURE 6 is a perspective view of the reflector of this invention in its erected configuration and equipped as an antenna for high frequency radio waves.

Referring more particularly to the drawings, there is shown in FIG. 1 a reflector **10** in the form of a paraboloid of revolution which is a preferred embodiment of the invention. The reflector **10** is shown mounted on a tripod stand **11** and erected in operational configuration for use as an antenna reflector of microwave energy. The reflecting surface of the reflector is provided by a thin membrane **12** of flexible electrically-conductive material which is stretched across a plurality of articulated ribs **13**. The membrane, which might be a metal coated fabric such as Dacron or the like, onto which a coating of silver, aluminum, or other conductor has been applied, is secured along the length of each rib in any convenient manner as by an adhesive or a lacing cord threaded through the fabric and wrapped around the rib. Each rib is joined at one end by an articulation joint **14** to an elongate rigid member **15** at a flanged end or hub **16** of the elongate member which represents the vertex of the paraboloid. Each of the ribs **13**, as shown in FIG. 5, is also provided with an articulation joint **17** at approximately its midpoint and is comprised of two rigid sections **13***a* and **13***b*, respectively, which are in the form of hollow metallic

structures of aluminum, stainless steel, electro-formed nickel, or like substance.

The articulation joints **17** and **14** permit the ribs to be folded through approximately 90 degrees at the hub in the direction of the elongate member **15** and approximately 180 degrees at their midpoints in the same direction. In the operational configuration of the reflector each rib assumes the form of a sector of a paraboloid or a parabolic arc and the reflecting membrane is drawn taut across the ribs from the flanged end of the axial member to the rib extremities to thereby define the paraboloid of revolution. As shown in FIGS. 1 and 6, the membrane is attached to the concave inner surfaces of the ribs whereby the ribs will not obstruct its inner reflecting surface.

The articulation joints for the ribs are provided by a pair of elongate metallic leaf springs which extend generally parallel to one another in the longitudinal direction of the rib as illustrated in FIG. 5 by the springs **14*a*** and **14*b*** in the joint **14**, and springs **17*a*** and **17*b*** in the joint **17**. Each spring is a thin metal strip which is bolted at its ends to the two rib sections. The strips may be folded any number of times as long as the radius of the bend is such that the elastic limit of the material is no exceeded. When unfolded in natural configuration the springs assume rigidity and buckling resistance, and thus possess a built-in self-locking feature. The strips may be fabricated of heat treated steel or beryllium copper processed to have a high elastic limit and chosen for negligible creep over the temperature-time profile. The use of two spaced strips at each joint provides desired cross-sectional inertia.

The elongate member **15** of the reflector is a tubular structure which, in the erected configuration of the reflector, coincides with the axis of the paraboloid. The end **16** of the elongate member is in the form of an annular flange to which the ribs of the reflector are joined at their base and radiate therefrom. The end **16** corresponds to the vertex of the paraboloid of revolution.

In the collapsed condition of the reflector, as shown in FIG. 2, the articulated ribs are folded at their midpoint articulation joints and the free ends of the ribs are held adjacent the elongate member **15** by an annular retaining band **21** such as a plastic ring, fabric belt, or the like. The folded ribs are also held against the axial member at their midpoint folds by means of resilient latching tabs **22**, one of which is provided on each rib near its midpoint and releasably engages a dielectric holding ring **23** which is secured by radial spokes **24** to the elongate axial member **15** in concentric relation therewith. Each latching tab is in the form of a strip of resilient material such as magnesium, aluminum, or the like, and is secured at one end to the outermost rib section **13*a*** and adapted to lie flat against the rib when the reflector is erected. When the rib is folded, however, the free end of the latching tab is placed inside the circle of the dielectric holding ring, as shown in FIG. 3, and thereby holds the folded rib adjacent the elongate axial member by engaging the inner edge of the holding ring, whereby the reflector is maintained in the folded condition. To avoid the possibility of cold welding of the tabs and springs, the springs are coated with plastic, such as Teflon.

For erecting the reflector to its operational configuration it is only necessary to remove the retainer band **21** from around the tips of the reflector ribs. Upon removal of the retainer band the leaf spring connections urge the ribs to unfolded condition with the rib sections **13*a*** swinging outwardly in the direction as indicated in FIG. 3, whereupon the latching tab of each rib is released from the holding ring **23**. The resilient springs at the rib articulation joints snap each rib into its relaxed condition in the naturally curved shape of a parabola. In the erected "locked" position of the ribs the membrane is held taut so that substantially a paraboloid surface of revolution is formed as shown in FIGS. 1 and 6.

In fabricating the resilient springs at the rib joints increased strength and buckling resistance is achieved by



providing each spring with a curvature at right angles to its length. One strip of each pair is wider than the other and sized for taking the overturning loads during erection. The thickness of each strip is determined by consideration of the stresses imposed on it during formation from the straight to the folded condition and the ratio of the folded diameter to the thickness is chosen whereby the combined bending and flattening stresses are well below the elastic limit of the material, thus insuring reliability.

Where the reflector is used in an antenna system for directing radio waves in a beam, a conventional radiator **61** positioned at the focal point of the reflector can be installed in any conventional manner and connected to a transmitter (not shown) by a transmission line **62** which extends through the tubular axial member **15** of the reflector. Any conventional means may be employed for fixing the reflector position relative to the tripod. A handle **63** may also be provided.

It will be apparent that the configuration of the reflector shown in FIGS. 1 and 6 is an approximate paraboloid of revolution and the correspondence to a true paraboloid increases as the number of ribs which are used in the construction increases. While parabolic reflectors are widely used because of their focusing abilities, it would be possible, of course, to fabricate reflectors with other contours, as for example, a spherical segment. The construction of the reflector and the method of erection could also be applied to such devices as umbrellas, solar collectors, and the like, where automatic erection and a high degree of mobility and portability are desired.

It will therefore be seen that a reflector is disclosed herein which is collapsible and reducible to a small packageable size, is of light weight, and demonstrates a high degree of portability suitable for a variety of applications. For erecting the reflector to its operational configuration, only a single retaining band need be slipped off the tips of the folded ribs, whereupon the resilient springs at the rib articulation joints, by unfolding and snapping into natural rigid condition, provide the energy for automatic erection of the reflector. With their built-in self-locking feature, the springs also lock the reflector in its operational configuration and thereby eliminate the need for auxiliary locking devices.

It will also be apparent that the novel method of folding the reflector disclosed herein also eliminates the possibility of cold welding of moving parts if the reflector is used in a hard vacuum environment. It also eliminates the need for using expensive exotic materials for bearing surfaces, and since it does not require lubrication of joints, possesses a far greater degree of reliability than conventional reflectors. Furthermore, the problem of dust, which would have a very adverse effect on hinged connections, particularly on a reflector intended for use in a hard vacuum environment such as, for example, on the lunar surface, is totally absent.

It should also be understood that the foregoing disclosure relates only to preferred embodiments of the invention and that it is intended to cover all changes and modifications of the examples in the invention herein chosen for the purposes of the disclosure and which do not constitute departure from the spirit and scope of the invention.

What is claimed and desired to be secured by Letters Patent is:

**1.** A collapsible reflector adapted to automatically erect to the operational configuration of a paraboloid of revolution, said reflector comprising:

an elongate support member;

a plurality of articulated rib members, each normally assuming the form of a parabolic arc;

first connecting means joining one end of each said rib member to one end of said elongate support member whereby said rib members are adapted to articulate in the direction of the elongate support member;

second connecting means for articulating each said rib member at approximately its midpoint whereby each said rib member is adapted to be folded in the direction of the elongate support member, said first and second connecting means each consisting of resilient leaf springs extending in the longitudinal direction of its associated rib member whereby the rib member is biased by the resilient leaf springs to its normally unfolded condition in the form of a parabolic arc;

a sheet of reflective material attached to each said rib member in a taut condition when said rib members are in their normally unfolded condition; and

means for releasably latching each said rib member in a folded retracted condition adjacent said elongate support member.

2. A collapsible reflector adapted to automatically erect to the operational configuration of a surface of revolution, said reflector comprising:

an elongate support member;

a plurality of articulated rib members, each normally assuming the form of a curved arc which is the generatrix of said surface of revolution;

first connecting means joining one end of each said rib member to said elongate support member at a common point on said support member whereby said rib members are adapted to articulate in the direction of the elongate support member;

second connecting means for articulating each said rib member at approximately its midpoint whereby each said rib member is adapted to be folded in the direction of the elongate support member, said first and second connecting means each consisting of resilient leaf springs extending in the longitudinal direction of its associated rib member whereby the rib member is biased by the resilient leaf springs to its normally unfolded condition in the form of said curved arc;

a sheet of reflective material attached to each said rib member in a taut condition when said rib members are in their normally unfolded condition; and

means for releasably latching each said rib member in a folded retracted condition adjacent said elongate support member.

3. A collapsible reflector as described in claim 2 and including means for releasing said rib members from their folded retracted condition to free each said rib member for movement by said leaf springs to its normal form of a curved arc whereby said sheet of reflective material assumes the form of a surface of revolution.

4. A collapsible reflector adapted to automatically erect to the operational configuration of a paraboloid of revolution, said reflector comprising:

an elongate support member;

a plurality of articulated rib members, each normally assuming the form of a parabolic arc;

first connecting means joining one end of each said rib member to one end of said elongate support member whereby said rib members are adapted to articulate in the direction of the elongate support member;

second connecting means for articulating each said rib member at approximately its midpoint whereby each said rib member is adapted to be folded in the direction of the elongate support member, said first and second connecting means each consisting of resilient leaf springs extending in the longitudinal direction of the rib member whereby the rib member is biased by the resilient leaf springs to its normally unfolded condition in the form of a parabolic arc;

a sheet of reflective material attached to the inner surface of each of said rib members in a taut condition when said rib members are in their normally unfolded condition;

restraint means for releasably maintaining said rib members in a restrained folded condition adjacent said elongate support member, said restraint means comprising cooperative latching means on said rib members and said elongate support member for releasably latching the folded ends of said rib members to said elongate support members; and

a restraining member in the form of a closed loop for engaging and enclosing the free ends of said rib members and maintaining the free ends of said rib members adjacent said elongate support member, said cooperable latching means being releasable by removal of said restraining member to free said rib members for movement to their normally unfolded condition whereby said sheet of reflective material is drawn taut and defines a paraboloid of revolution.

5. A collapsible reflector adapted to automatically erect to the operational configuration of a paraboloid of revolution, said reflector comprising:

an elongate support member;

a plurality of articulated rib members, each normally assuming the form of a parabolic arc which constitutes the generatrix of said paraboloid of revolution;

first joint means for articulately joining one end of each said rib member to one end of said elongate support member with the concave surface of the rib member facing said elongate support member whereby said rib members are adapted to articulate in the direction of the elongate support member;

second joint means for articulating each said rib member at approximately its midpoint whereby each said rib member is adapted to be folded in the direction of the elongate support member, said first and second joint means biasing said rib members to their normally unfolded condition;

a sheet of microwave reflective material attached to the concave inner surface of each of said rib members in a taut condition when said rib members are in their normally unfolded condition;

restraint means for releasably maintaining said rib members in a restrained folded condition adjacent said elongate support member, said restraint means comprising cooperative latching means on said rib members and said elongate support member for releasably latching the folded ends of said rib members to said elongate support member; and

a restraining member in the form of a closed loop for engaging and enclosing the free ends of said rib members and maintaining the free ends of said rib members adjacent said elongate support member, said cooperable latching means being releasable by removal of said restraining member to free said rib members for movement to their normally unfolded condition whereby said sheet of reflective material is drawn taut and defines a paraboloid of revolution.

6. A collapsible reflector as described in claim 5 wherein said elongate support member is tubular in form and is thereby adapted to receive therethrough the cable feed for a microwave radiator located at the focal point of the paraboloid of revolution.

7. A collapsible reflector adapted to automatically erect to the operational configuration of a paraboloid of revolution, said reflector comprising:

an elongate support member;

a plurality of articulated rib members, each normally assuming the form of a parabolic arc;

first connecting means joining one end of each said rib member to one end of said elongate support member whereby said rib members are adapted to articulate in the direction of the elongate support member;

second connecting means for articulating each said rib member at approximately its midpoint whereby each said rib member is adapted to be folded in the direction of the elongate support member, said first and second connecting means each consisting of resilient leaf springs extending in the longitudinal

direction of its associated rib member whereby the rib member is biased by the resilient leaf springs to its normally unfolded condition in the form of a parabolic arc; and

a sheet of reflective material attached to each said rib member in a taut condition when said rib members are in their normally unfolded condition.

**8.** A collapsible reflector adapted to automatically erect to the operational configuration of a paraboloid of revolution, said reflector comprising:

an elongate support member;

a plurality of articulated rib members, each normally assuming the form of a parabolic arc;

first connecting means joining one end of each said rib member to one end of said elongate support member whereby said rib members are adapted to articulate in the direction of the elongate support member;

second connecting means for articulating each said rib member at approximately its midpoint whereby each said rib member is adapted to be folded in the direction of the elongate support member, said first and second connecting means each consisting of resilient leaf springs extending in the longitudinal direction of its associated rib member whereby the rib member is biased by the resilient leaf springs to its normally unfolded condition in the form of a parabolic arc;

a sheet of reflective material attached to each said rib member in a taut condition when said rib members are in their normally unfolded condition;

means for releasably latching each said rib member in a folded retracted condition adjacent said elongate support member, said latter means comprising a dielectric member in the form of a closed loop attached to and enclosing said elongate member and a resilient tab on each said rib member engageable with the dielectric member to hold the rib member adjacent the elongate support member.

**9.** A collapsible reflector adapted to automatically erect to the operational configuration of a paraboloid of revolution, said reflector comprising:

an elongate support member;

a plurality of articulated rib members, each normally assuming the form of a parabolic arc;

first connecting means joining one end of each said rib member to one end of said elongate support member



whereby said rib members are adapted to articulate in the direction of the elongate support member;

second connecting means for articulating each said rib member at approximately its midpoint whereby each said rib member is adapted to be folded in the direction of the elongate support member, said first and second connecting means each consisting of a pair of elongate resilient leaf springs extending in the longitudinal direction of its associated rib member whereby the rib member is biased by the resilient leaf springs to its normally unfolded condition in the form of a parabolic arc and said leaf springs being curved transversely to provide means for locking the rib members in their unfolded condition; and

a sheet of reflective material attached to each said rib member in a taut condition when said rib members are in their normally unfolded condition.

**10.** A collapsible reflector adapted to automatically erect to an operational configuration, said reflector comprising:

an elongate support member;

a plurality of articulated rib members;

first connecting means joining one end of each said rib member to said elongate support member whereby said rib members are adapted to articulate in the direction of the elongate support member;

second connecting means for articulating each said rib member at approximately its midpoint whereby each said rib member is adapted to be folded in the direction of the elongate support member, said first and second connecting means each consisting of resilient leaf spring means extending in the longitudinal direction of its associated rib member whereby the rib member is biased by the resilient leaf spring means to its normally unfolded condition; and

a sheet of reflective material attached to each said rib member in a taut condition when said rib members are in their normally unfolded condition.

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